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Project 2.01 | Grammar-based Automatic 3D Model Reconstruction from Terrestrial Laser Scanning Data

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Objectives Investigate a grammar-based method for automatic 3D model reconstruction from segmented data extracted from terrestrial or mobile laser scanning devices

Develop the proof of concept framework for automatic model reconstruction

Outcomes A prototype of 3D city model reconstruction software system

Automatic model update algorithms for existing models within the interests of industry i.e. AAM company

In recent years, 3D models have been used in a variety of applications, and the steadily growing capacity in both quality and quantity are increasing demand. In order to cover the requirements and to keep the existing models up to date, automatic reconstruction methods are needed to avoid the labour intensive and time consuming manual processing workflow. Our proposed method aims to derive a structure description of a whole 3D building by using a pre-defined grammar and rules, which are applied in an automated data-driven reconstruction process. Our main contribution is to apply a formal grammar directly on the 3D data set to develop a systematic method for automated 3D building model reconstruction.

1. System Overview

As shown in Figure 1, segmented data needs to be converted into 3D shapes in order to support the user-defined grammar and rules, which are derived from 3D building structures. To drive the building reconstruction process, a grammar engine is proposed to apply the appropriate rules for the given shape to break it down into the elementary objects.

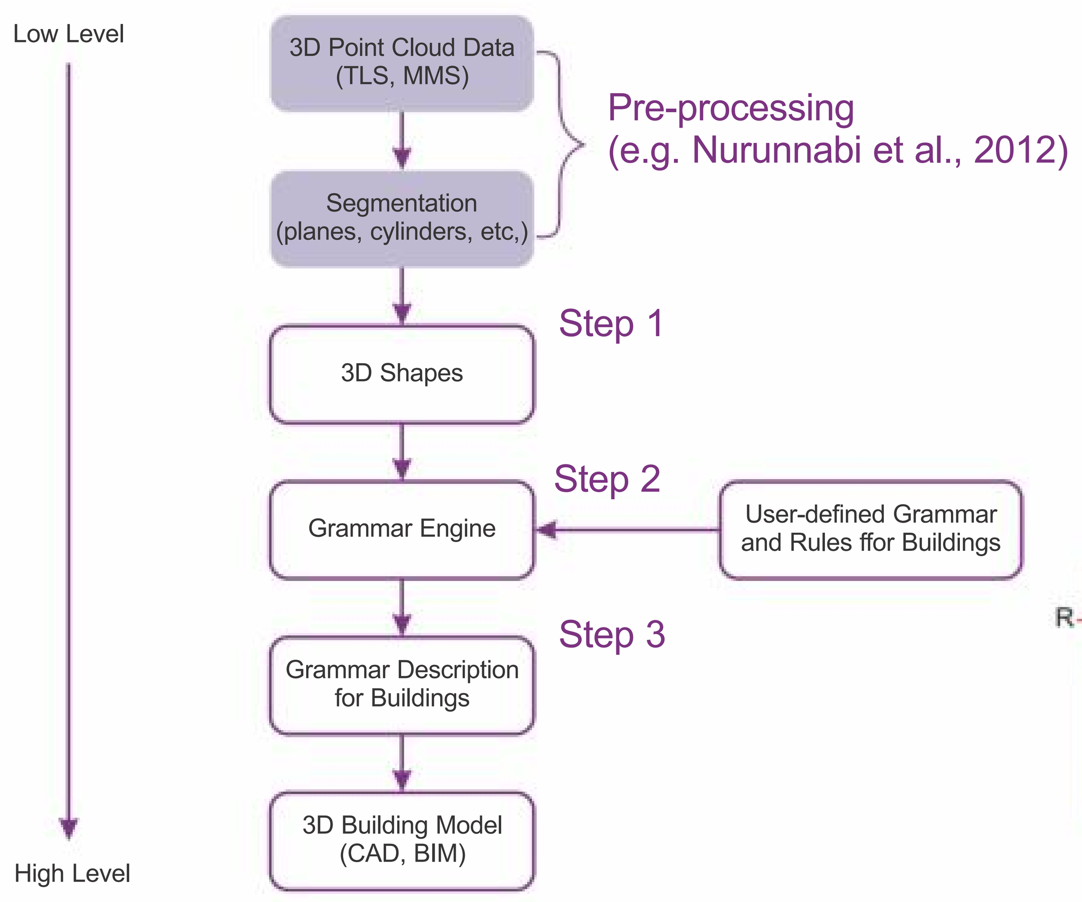


Figure 1: The work flow for proposed building model reconstruction system

2. Grammar and Rules

Formally a grammar is defined as a four-tuple $G = (T, N, R, I)$. The terminal symbols T and the nonterminal symbols N build the alphabet of the grammar. The non-terminal symbols can be replaced by other non-terminal or terminal children, while terminal symbols cannot be subdivided further. R is a set of production or replacement rules, and I is the initial symbol, a non-terminal symbol which defines the initial point for all replacement. A context-free grammar (CFG) is applied for our case, which implies that R contains rules of the form $N \rightarrow (T \sqcup N)^{*}$. In other words, a non-terminal symbol on the left side can be replaced by a number of terminal and non-terminal symbols on the right side.

Example of Building Grammar and Rules

- $G_B = (T_B, N_B, R_B, I_B)$
- T_B Building terminals (e.g. wall element, window element, door element…)
- N_B Building non-terminals (e.g. part of building)
- R_B A set of rules for buildings
- I_B Initial symbols

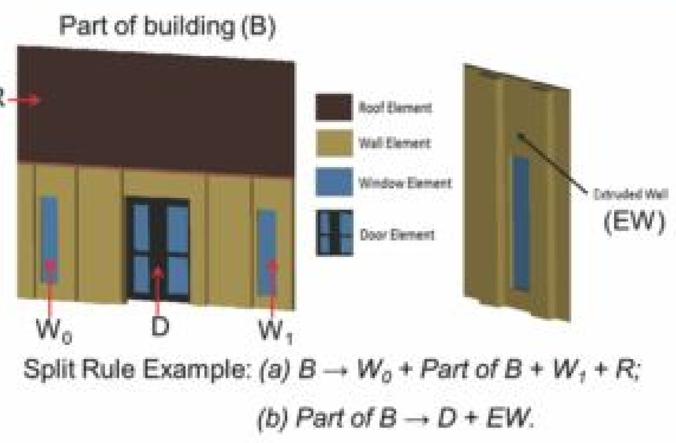


Figure 2: Example for the terminal symbols of buildings. Extruded wall that includes inset window structure and stick-out wall parts is shown on the right hand side.

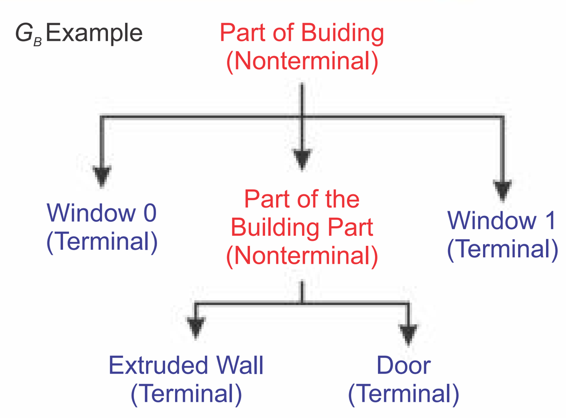
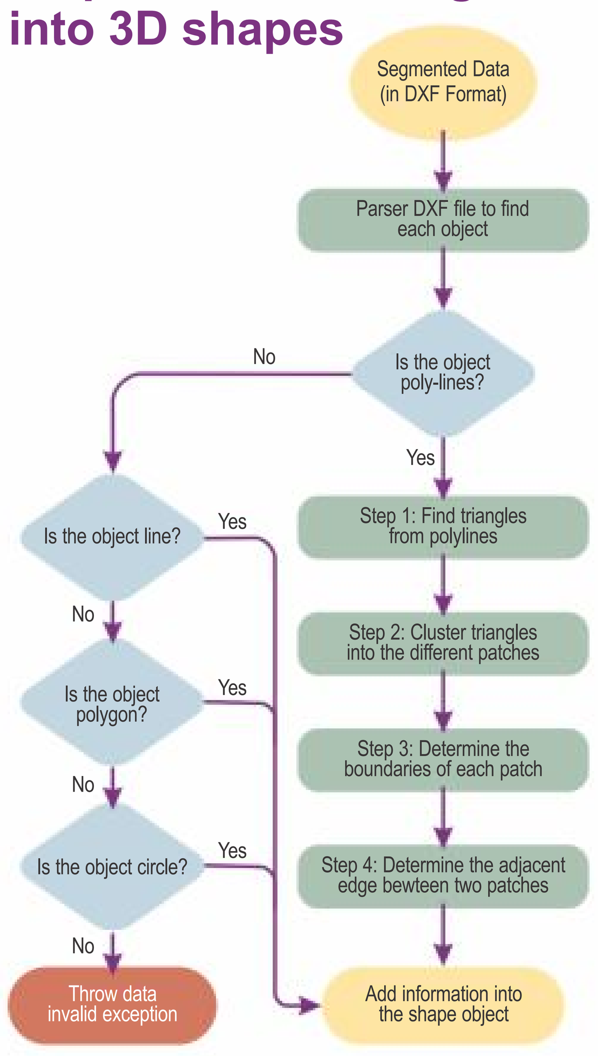


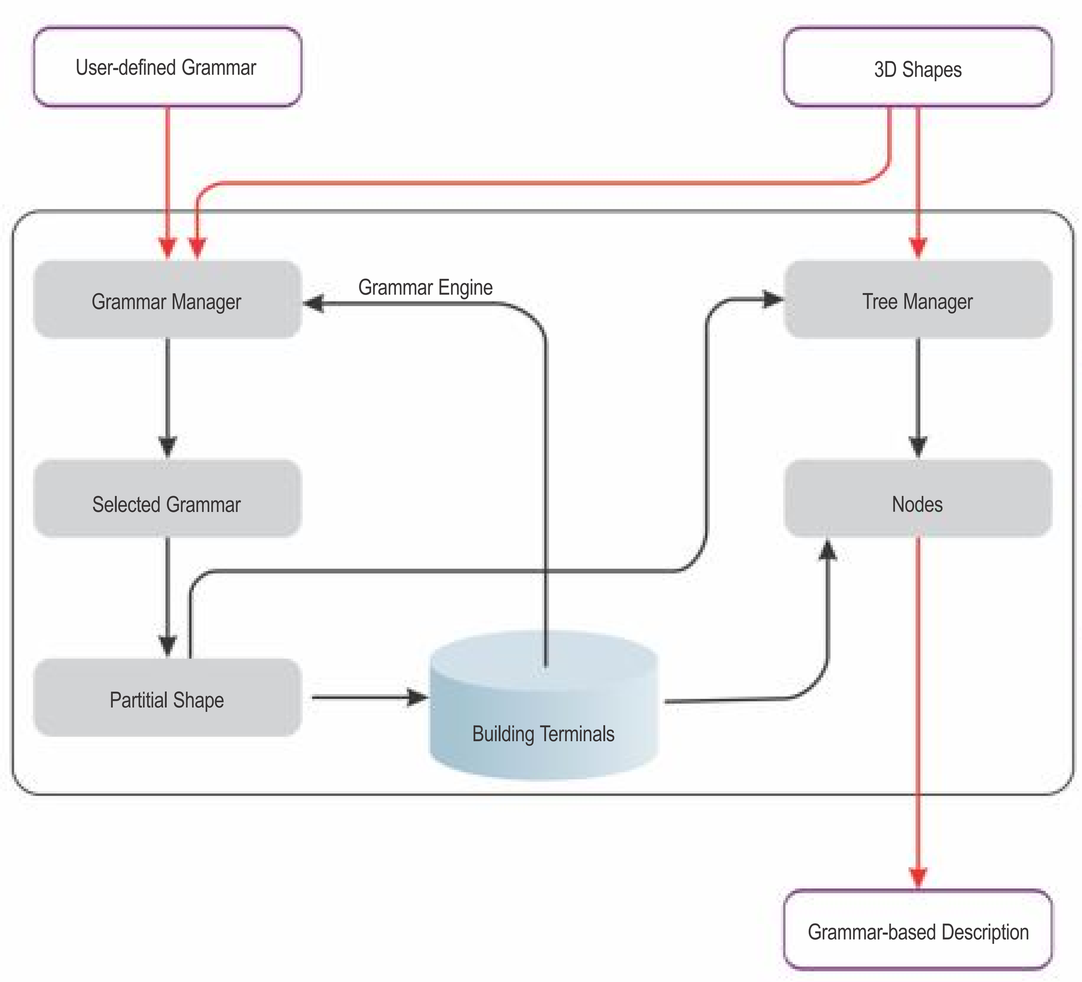
Figure 3: Example of a tree structure from building model derivation according to the split rules.

3. Grammar-based 3D Model Reconstruction Method

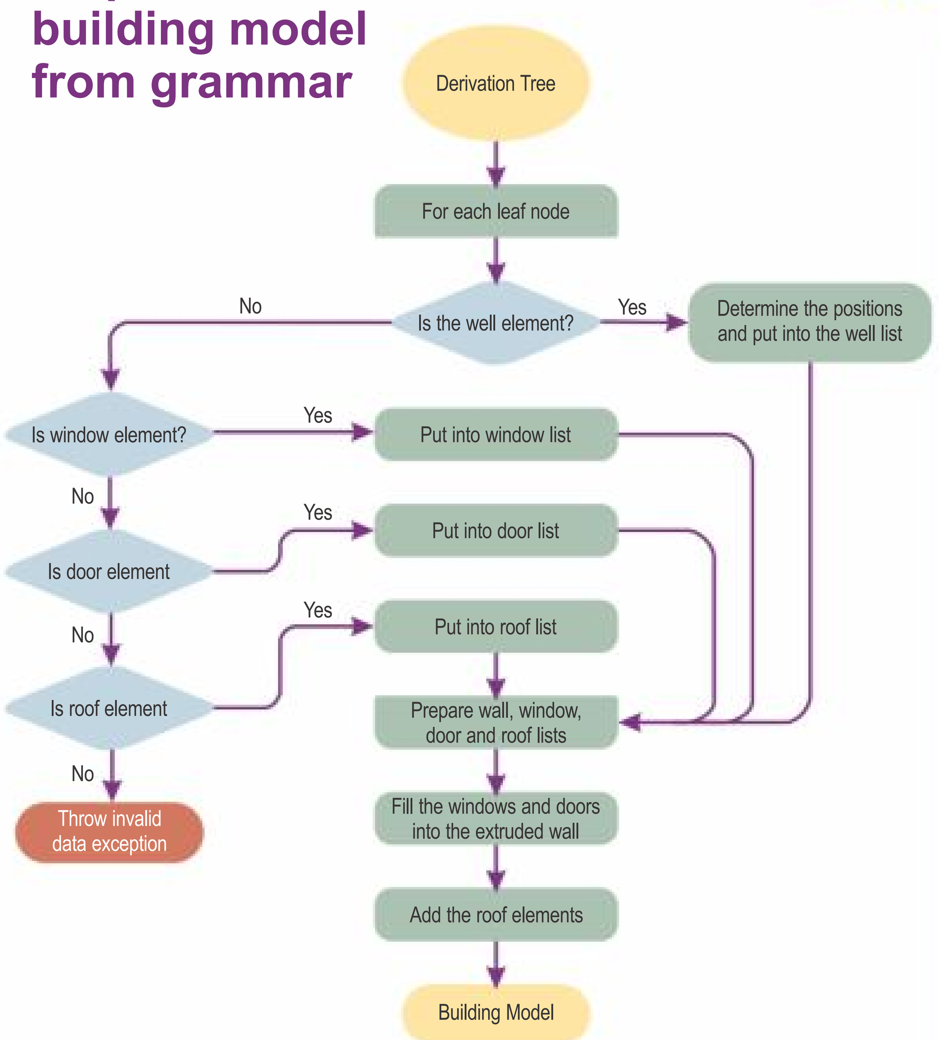
Step 1 – Convert segmented data into 3D shapes



Step 2 – Grammar Engine



Step 3 – Generate building model from grammar



4. Results

Figure 4: 3D point cloud for the building . Currently the 3D point cloud is used to generate a sketch up description - this generates the DXF file in Figure 5.

Figure 5: 3D visualisation of segmented building structures in DXF

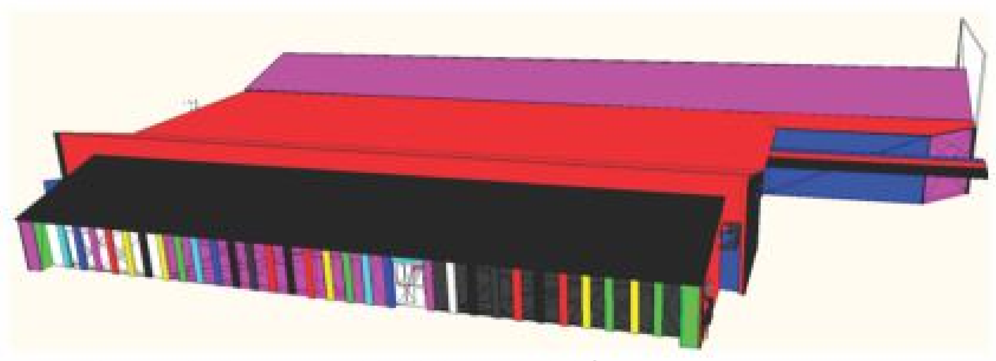


Figure 6: Processed building model from segmented data

Figure 7: Expected reconstructed building model from segmented data. Different terminal elements are shown in different colours. Window elements are in blue, wall elements are in gold and the roof is in brown.

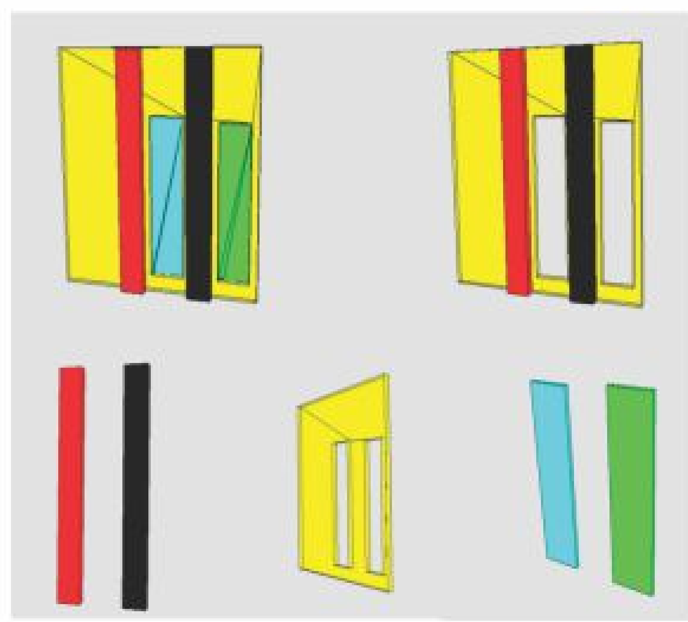


Figure 8: Demonstration of detailed building reconstruction for small samples. Reconstructed objects include wall panel, extruded wall and windows.

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